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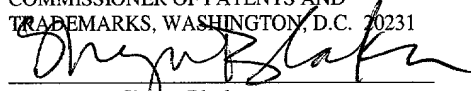
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**SYSTEM AND METHOD
FOR STABILIZING THE HUMAN SPINE
WITH A BONE PLATE**

By:

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BACKGROUND OF THE INVENTION

1. Cross Reference to Related Applications

This is a continuation of copending U.S. Pat. Appl. Ser. No. 09/089,027 filed June 2, 1998; which is a continuation-in-part U.S. Pat. Appl. Ser. No. 08/905,823, filed August 4, 1997, now abandoned.

2. Field of the Invention

The present invention generally relates to spinal fixation systems and the like. More particularly, the present invention relates to a spinal plate system includes a mechanism for fixably attaching screws to a plate at a selected angle determined according to the patient's anatomy.

3. Description of Related Art

The use of spinal fixation plates for correction of spinal deformities and for fusion of vertebrae is well known. Typically, a rigid plate is positioned to span bones or bone segments that need to be immobilized with respect to one another. Bone screws may be used to fasten the plate to the bones. Spinal plating systems are commonly used to correct problems in the lumbar and cervical portions of the spine, and are often installed posterior or anterior to the spine.

Spinal plate fixation to the cervical portion of the spine can be risky because complications during surgery can cause injury to vital organs, such as the brain stem or the spinal cord. When attaching a fixation plate to a bone, bone screws are placed either bi-cortically or uni-cortically through the bone. Uni-cortical positioning of bone screws has grown in popularity because it is inherently safer to use. Bi-cortical screws are intended to breach the distal cortex for maximum anchorage into the bone; however, this

may place distal soft tissue structures at risk. Screw placement is of particular importance in anterior cervical plate procedures because of the presence of the spinal cord opposite the distal cortex. Unfortunately, because of the soft texture of the bone marrow, the uni-cortical screws may undergo movement from their desired positions. In fact, the portion of the bone surrounding such screws may fail to maintain the screws in their proper positions, resulting in screw backout.

Screw backout is particularly a problem when a pair of screws are implanted perpendicular to the plate. When the screws are placed in such a manner, screw backout can occur as a result of bone failure over a region that is the size of the outer diameter of the screw threads. To overcome this problem, a different configuration of the screws has been developed in which two screws are angled in converging or diverging directions within the bone. Advantageously, the amount of bone that is required to fail before screw backout can occur is increased by this configuration as compared to screws which are implanted in parallel. Although positioning screws angled toward or away from each other in a bone reduces the risk of a screw backout, such backouts can still happen. The result of a screw backout can be damaging to internal tissue structures such as the esophagus because a dislocated screw may penetrate the surface of such structures.

In an attempt to reduce the risk of damage to internal tissue structures, some cervical screw plate systems have been devised in which uni-cortical screws are attached to the plate and not just the bone. It is intended that if screw backout occurs, the screw will remain connected to the plate so that it cannot easily contact internal tissue structures. One such system is described in U.S. Patent No. 5,364,399 to Lowery et al. and is incorporated by reference as if fully set forth herein. This plating system includes a locking screw at each end of the plate which engages the heads of the bone screws to trap them within recesses of the plate. Since the locking screw is positioned over portions of the bone screws, it may extend above the upper surface of the plate. Thus, the locking screw may come into contact with internal tissue structures, such as the esophagus. Unfortunately, breaches to the esophageal wall may permit bacterial contamination of

surrounding tissues, including the critical nerves in and around the spinal cord, which can be fatal.

Another plating system that includes a screw to plate ring is the Aline™ Anterior Cervical Plating System sold by Smith & Nephew Richards Inc. in Memphis, Tennessee. A description of this system can be found in the Aline™ Anterior Cervical Plating System Surgical Technique Manual available from Smith & Nephew Richards Inc. and is incorporated by reference as if fully set forth herein. The bone screws of this system have openings within each bone screw head for receiving a lock screw coaxially therein. Each bone screw may be inserted into a bone such that the head of the screw is positioned within a borehole of a plate placed adjacent to the bone. The head of each bone screw is slotted such that portions of the head may be deflected toward the plate during insertion of the lock screw within the opening of the bone screw. The bone screw may be thusly locked against the plate. However, inserting the lock screw into and fixably positioning the lock screw within the opening may be difficult since the lock screw is very small. The surgeon may be unable to hold onto the lock screw without dropping it. Unfortunately, once such a tiny screw falls into the surgical wound, it may be unretrievable.

SUMMARY OF THE INVENTION

In accordance with the present invention, a spinal plating system is provided that largely eliminates or reduces the aforementioned disadvantages of conventional spinal plating constructions. An embodiment of the invention relates to an implant system for fixation of the human spine that includes a plate having end boreholes, midline boreholes, screws, and expandable/contractible rings.

The end boreholes preferably extend from the upper surface to the lower surface of the plate. The end boreholes may be disposed in pairs at opposite ends of the plate. Each end borehole is preferably sized to receive at least a portion of a head of a screw

therein. Each end borehole is also preferably spherical shaped to permit the screw to be “obliquely angulated” relative to the plate. Herein, “obliquely angulated” is taken to mean that the screw may be positioned at a wide range of angles relative to the plate, wherein the range of angles is preferably from 0 degrees to about 15 degrees from an imaginary axis that is perpendicular to the plate. Since the screws may be obliquely angulated with respect to the plate, the occurrence of screw backout from a bone may be significantly reduced.

The expandable/contractible rings are preferably sized so that they may be positioned within each borehole between the plate and each of the screw heads. The inner surface of each ring is preferably shaped to mate with a screw head while the outer surface is preferably shaped to mate with the plate. The outer surface of each screw head may be tapered such that an upper portion of the head is larger than a lower portion of the head. Each ring may also have a gap that extends vertically through the ring to render it expandable/contractible. Thus, during insertion of a screw head within a bone, the ring preferably exerts a compressive force on the screw head to fixably connect the screw to the plate. The screw may be prevented from contacting tissue structures that are protected by the spine even when screw backout occurs since the screw is attached to the plate.

The midline boreholes may be formed through the plate at various locations along a midline axis extending across the plate. The surface of the plate that surrounds each midline borehole is preferably tapered. Further, the heads of screws that may be positioned within the plates preferably have tapered outer surfaces that are shaped to mate with the tapered surface of the plate. Thus, when such a screw head is inserted into a midline borehole, the shape of the plate causes the screw to become fixably attached to the plate in a position that is substantially perpendicular to the plate. Since the midline boreholes may be used when inserting screws into bone graft, oblique angulation of screws positioned within the midline boreholes is not required.

Prior to surgical implantation of the spinal plate system, the expandable/contractible rings may be placed within the end boreholes of the plate. The plate may then be positioned adjacent to a portion of the spine that requires spinal fixation. Holes may be drilled and tapped into a portion of the bone underlying each end borehole at the desired angle. Screws may be inserted through the end boreholes into the holes, and the heads of the screws may be positioned within the boreholes such that the rings surround at least a portion of the heads. Advantageously, during insertion of the screws, the rings preferably lock the screws in place without occupying regions outside of the boreholes. Further, since the rings are pre-positioned within the end boreholes, surgeons do not have to worry that they may drop the rings during insertion of the screws.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages of the present invention will become apparent to those skilled in the art with the benefit of the following detailed description of a preferred embodiment and upon reference to the accompanying drawings in which:

FIG. 1 is a top plan view of one embodiment of a spinal plating system that may be used for fixation of the human spine;

FIG. 2 is a cross-sectional view of the spinal plating system along plane I of FIG. 1;

FIG. 3 is a cross-sectional view of a screw within an end borehole of a plate, wherein the screw is positioned according to one embodiment of the present invention;

FIG. 4 is a cross-sectional view of the screw, wherein the screw is positioned according to another embodiment;

FIG. 5 is a cross-sectional view of the spinal plating system along plane II of FIG. 1, wherein a pair of screws extend in diverging directions, according to one embodiment;

FIG. 6 is a cross-sectional view of the spinal plating system along plane II of FIG. 1, wherein the pair of screws extend in converging directions, according to another embodiment;

FIG. 7 is a side view in partial cross-section of a spinal fixation system that includes a screw, a ring, and a plate;

FIG. 8 is a top view of an embodiment of the plate depicted in FIG. 7;

FIG. 9 is a cross-sectional view of a tapered screwhead connected to a tapered ring through a threaded engagement;

FIG. 10A is a cross-sectional view of a ring having a tapered inner surface;

FIG. 10B is a cross-sectional view of a ring having a non-tapered inner surface;

FIG. 11A is a cross-sectional view of a screw head having a tapered outer surface;

FIG. 11B is a cross-sectional view of a screw head having a non-tapered outer surface;

While the invention is susceptible to various modifications and alternative forms, specific embodiments thereof are shown by way of example in the drawings and will herein be described in detail. The drawings may not be to scale. It should be understood, however, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all

modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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Fig. 1 depicts a top plan view of an embodiment of a spinal plating system. The spinal plating system may be used to correct problems in the lumbar and cervical portions of the spine. For example, the plating system may be implanted into the occiput bone which is located at the base of the skull. The plating system is preferably installed
10 anterior to the spine. The spinal plating system preferably includes a plate 10 that may be placed adjacent to a portion of the spine. The length of plate 10 is preferably chosen so that the plate may span between at least two vertebrae. Plate 10 preferably includes a pair of end boreholes 12 and 14 located at opposite ends 16 of plate 10. End boreholes 12 and 14 are preferably formed vertically through plate 10 such that they extend from an upper
15 surface to a lower surface of the plate. End boreholes 12 and 14 are preferably spaced from a longitudinal midline axis 21 of plate 10 by the same distance.

End boreholes 12 and 14 are preferably shaped to receive the heads of bone screws 20 during spinal implantation. The spinal plating system further includes rings 18
20 that may be disposed within each of the end boreholes 12 and 14 for fixedly attaching bone screws 20 to plate 10. A gap 19 preferably exists in each of the rings 18 to enable the rings to contract or expand under pressure. The spinal plating system may also include midline boreholes 22 that extend vertically through plate 10 at some point along the midline axis 21 of plate 10. Preferably, one of the midline boreholes 22 is located at
25 the middle of plate 10 while the other midline boreholes are offset from the middle. The head of screw 24 may be positioned within one of the midline boreholes 22. This configuration of midline boreholes 22 may provide a surgeon with more options as to the location of a screw 24 so that the screw may be placed in the most desirable location. Such a screw 24 may be used to connect plate 10 to bone graft. Those elements that
30 make up the spinal plating system are preferably composed of steel, pure titanium, or of

titanium alloys because such materials are generally nontoxic, biocompatible, strong, and noncorrosive. Other materials which have these properties may also be used to form the elements.

Fig. 2 illustrates a cross-sectional view of the spinal fixation system along plane I of Fig. 1. Particularly, Fig. 2 shows how screw 24 is attached to plate 10 within one of the midline boreholes 22. Screw 24 preferably includes a head 26 and a shank 28 that extends from the base of head 26. The inner surface of a portion 30 of plate 10 that surrounds borehole 22 is preferably tapered, making borehole 22 larger at the top than at the bottom. The outer surface of head 26 is also preferably tapered so that head 26 may fit snugly within borehole 22. In fact, the shape of plate 10 and head 26 preferably promotes attachment of screw 24 to plate 10. During implantation of screw 24 into bone graft, the shank of the screw is preferably screwed into a hole that has been formed in the bone graft underlying borehole 22. Because the bottom portion of borehole 22 is smaller than the upper portion of the screw head 26, screw 24 may become locked into place within borehole 22 once it has been screwed to a desired depth within the bone graft. The plate is also shown as having a slight curvature to enhance its fixation to the spine.

Fig. 3 depicts a cross-sectional view of an embodiment of one of the end boreholes 12 and 14 in which screw 20 is disposed. Borehole 12 is preferably substantially spherical in shape so that a head 32 of screw 20 may be rotated and moved to various positions within borehole 12. Ring 18 is preferably sized to fit into borehole 12 between plate 10 and head 32. The outer surface of ring 18 is preferably curved to permit movement of the ring within borehole 12. The combination of ring 18 and borehole 12 is like that of a ball and socket since ring 18 may be rotated both horizontally and vertically in clockwise and counterclockwise directions within borehole 12. Ring 18 may also be rotated in directions that are angled away from the horizontal and vertical directions. In Fig. 3, ring 18 at least partially surrounds head 32 of screw 20 which is positioned within borehole 12. A shank 34 of bone screw 20 preferably has threading 36 to allow the screw to be inserted into a bone when it is rotated in a clockwise direction.

Head 32 preferably includes a cavity 42 that extends from the top of the head to an inner portion of the head. Cavity 42 may be shaped to receive the end of any fastening device e.g., a socket wrench, that may be used to turn screw 20.

5 Screw 20 may be simultaneously screwed into a bone and moved to its desired position. The inner surface of ring 18 and the outer surface of head 32 are preferably tapered and shaped to mate with each other. The bottom portion of head 32 is preferably smaller than the upper portion of ring 18. As screw 20 is inserted into a bone, head 32 preferably applies a radial force to ring 18, thereby causing the ring to expand within the
10 borehole and increase the size of gap 19. An interference fit may form between screw head 32, ring 18, and plate 10 in which these elements fit so tightly together that they obstruct the movements of each other. The hoop stress of ring 18 on head 32 may fixedly attach screw 20 to plate 10. Also during insertion of screw 20, screw head 32 and ring 18 may be positioned within borehole 12 such that their left sides are at a higher elevation
15 than their right sides. Fig.3 shows that positioning screw head 32 in this configuration may result in a centerline 38 of shank 34 being obliquely angulated with respect to plate 10. In fact, centerline 38 may be positioned where it is at an angle ranging from 0 to 15 degrees with respect to an imaginary axis 40 which is perpendicular to plate 10. Fig. 3 demonstrates shank 34 of screw 20 being angled to the left of imaginary axis 40 while
20 Fig. 4 demonstrates shank 34 being angled to the right of imaginary axis 40. Screw 20 is not limited to these positions and can be angled in various directions, such as into the page.

Fig. 5 and Fig. 6 depict different embodiments of the spinal plating system along
25 plane II of Fig. 1. Fig. 5 shows that screws 20 may be positioned within end boreholes 12 and 14 such that they extend in converging directions with respect to each other. The screws 20 depicted in Fig. 6 are shown as being positioned such that their shanks 34 extend in diverging directions with respect to each other. Screws 20 may be moved to such positions as described above. Since bone screws 20 may be placed in diverging or
30 converging directions through end boreholes 12 and 14 at both ends of plate 10, screw

backout may be greatly reduced. Further, the use of rings 18 to fixedly attach screws 20 to plate 10 may prevent damage to tissue structures by any screws that are able to escape from the bone. Rings 18 preferably do not extend above the upper surface of plate 10, and thus advantageously do not contact tissue structures. Screw 20 may be placed in a uni-cortical position within the bone since the problem of screw backout is greatly reduced by the diverging or converging screw configurations.

According to one embodiment, the spinal fixation system of Fig. 1 is prepared for surgical implantation by pre-positioning of rings 18 within end boreholes 12 and 14. During the actual surgical procedure, holes may be drilled and tapped into the bones to which plate 10 is to be attached. Plate 10 may then be positioned adjacent to the bones. Each of the screws 20 may be screwed into the bone holes while they are being positioned within their corresponding boreholes 12 and 14. Each pair of screws 20 at opposite ends 16 of plate 10 may be positioned so that shanks of the screws are at oblique angles relative to the plate. The insertion force of each screw 20 into each ring 18 preferably causes the ring to exert a compressive force on the screw head, thereby fixably connecting the screws to plate 10. If necessary, screw 24 may be positioned in one of the midline boreholes 22 such that screw 24 attaches to plate 10.

Each of the features of the embodiments discussed above may be combined or used individually.

FURTHER IMPROVEMENTS

The following additional embodiments may be used individually or in combination with any of the embodiments described above.

A side view of an embodiment of a spinal plate system 100 is shown in Fig. 7. Spinal plate system 100 preferably includes a bone screw 120, a ring 118, and bone plate 110. Plate 110 may be used to stabilize a bony structure such as the spine to facilitate a

bone fusion (e.g., a spinal fusion). The bone screw 120 may be used to connect plate 110 to a bone such as a vertebra. Ring 118 preferably fixes bone screw 120 to plate 110 at a selected angle that depends upon the patient's anatomy. Bone screw 120, ring 118, and bone plate 110 are preferably capable of being used in similar applications as screw 20, ring 18, and plate 10 as previously described in Figures 1-6.

A top view of an embodiment of plate 110 is shown in Fig. 8. Plate 110 preferably includes one or more boreholes 112 and may function similarly to plate 10 as described above. Each borehole 112 preferably has a curvate inner surface 113 (shown in Figure 7) for engaging the outer surface 123 of ring 118. The inner surface 113 preferably has the shape of a portion of an outer surface of a sphere. Borehole 112 has a width that is defined across the inner surface 113 of the borehole. The width of the borehole may vary in a direction axially through the borehole. In Fig. 7, for example, the width of the boreholes preferably increases from a top surface 102 of the plate to about the middle of the plate. The width of the borehole in Fig. 7 then preferably decreases from about the middle of the plate to a lower surface 104 of the plate such that the borehole has a maximum width near the midpoint between upper surface 102 and lower surface 104 of the plate.

The outer surface 123 of ring 118 is preferably curvate for engaging the inner surface 113 of the borehole. The shape of surfaces 123 and 113 preferably allow ring 118 to swivel within the borehole. The swiveling action may be similar to that of a ball and socket joint. The ring preferably surrounds at least a portion of the head 125 of a bone screw. The enlarged end 127 disposed on head 125 is optional and need not be included if it inhibits angulation of the bone screw. The swiveling of the ring within the borehole preferably enables the shank 135 of the bone screw 120 to rotate in a substantially conical range of motion. In this manner, the head is preferably movable within the borehole, and the shank is adjustably positionable at a plurality of angles substantially oblique to the plate.

In an embodiment, the surfaces 123 and 113 are preferably shaped to provide a conical range of motion to the shank that is within a preferred range of angles. The head is preferably movable within the borehole such that the shank can be positioned at a selected angle relative to an imaginary axis running perpendicular to the plate proximate borehole 112. The selected angle is preferably less than about 45 degrees, more preferably less than about 30 degrees, and more preferably still less than about 15 degrees.

Ring 118 preferably has an outer width that is less than or about equal to the width of borehole 112 at a location between upper surface 102 and lower surface 104 of the plate. In this manner, ring 118 may be positioned within borehole 112 proximate the middle of the borehole to enable the bone screw 120 to extend substantially perpendicularly from the bone plate 110. Prior to surgery, rings 118 are preferably pre-positioned within boreholes 112 of plate 110. "Pre-positioned" is taken to mean that the rings are capable of swiveling within the borehole but are preferably inhibited from falling out of the borehole because of the reduced width of the borehole proximate the upper and lower surfaces. The width of the borehole proximate the upper and lower surfaces of plate 110 is preferably less than or about equal to the outer width of the ring to inhibit the ring from falling out of the borehole. In this manner, the surgeon may use a plate 110 having rings 118 pre-positioned within the boreholes 112 such that the rings will not fall into the surgical wound when spinal system 100 is installed.

Alternately, the rings 118 can be manually positioned within the boreholes during surgery. Ring 118 preferably includes one or more slots or gaps 19 (as shown in Fig. 1). The slot preferable allows the ring to be contracted or expanded. Contraction of ring 118 may allow the ring to be positioned within the borehole during surgery. Once positioned within the borehole the ring preferably expands and is inhibited from falling out of the borehole.

The ring 118 is preferably capable of being swiveled such that one portion of the ring is adjacent to upper surface 102 of plate 110 while another portion of the ring lies adjacent to lower surface 104 of plate 110. The ring is preferably sufficiently thin to allow it to reside within the borehole without extending from the borehole beyond the upper surface 102 or lower surface 104 of the plate. Generally, it is preferred that the ring and screw head remain within the borehole 112 to minimize the profile width of spinal system 100. In some embodiments, however, the bone screw 120 may be capable of being angulated relative to the plate 110 such that the ring 118 extends from the borehole 112 beyond a surface of the plate 110.

The head 125 is preferably screwed into ring 118 to create a fixed connection between bone screw 120 and plate 110 at a selected angle. In an embodiment depicted in Fig. 9, screw head 125 preferably contains head threading 121 on its outer surface that is complementary to ring threading 119 contained on the inner surface of ring 118. The head threading 121 preferably mates with the ring threading 119 to enhance the connection between the bone screw 120 and the ring 118. The head 125 preferably has a cavity 142 formed on its upper surface for receiving a driving tool such as a screw driver or an allen wrench.

The outer surface of the head 125 is preferably tapered so that screwing the head into the ring causes a change in width (e.g., expansion) of the ring 118 to fix the bone screw 120 in position relative to the plate 110. The inner surface of the ring 118 may also be tapered to substantially match the taper on the outer surface of the head. At least a portion of the head 125 preferably has a width greater than the inner width of the ring 118. As the screw head is screwed into the ring 118, the ring preferably expands outwardly from its inner surface to accommodate the increasing width of the screw head 125. The ring 118 may contain a slot or gap 19 (as shown in Fig. 1) as previously described to facilitate expansion of the ring against the inner surface 113 of the borehole 112. The slot is preferably widened as a result of force received from head 125. The

force exerted by head 125 against the inner surface of ring 118 preferably presses the ring into a fixed engagement against inner surface 113 of borehole 112.

Alternatively, ring 118 may contain one or more partial slots 145, as depicted in Fig. 12. Each partial slot 145 preferably extends from a top 147 or bottom 149 of ring 118 into the ring. Partial slots may extend up to about midpoint 148 of ring 118. In one embodiment, a plurality of slots 145 may be oriented about the ring such that alternate slots extend from the top 147 and/or the bottom 149 of ring 118, as depicted in Fig. 12. These alternating partial slots preferably facilitate the expansion and contraction of ring 118.

Cross-sectional views of two embodiments of ring 118 are shown in Figs. 10A and 10B. The ring may contain an inner surface that is tapered (as shown in Fig. 10A) or that is substantially untapered (as shown in Fig. 10B). Cross sectional views of two embodiments of screw 120 are shown in Figs. 11A and 11B. The head 125 may have a substantially untapered outer surface (as shown in Fig. 11A) or a substantially tapered outer surface (as shown in Fig. 11B). It is to be understood that each of the heads of the screws depicted in Figs. 11A and 11B may be used in combination with either of the rings 118 depicted in Fig. 10A or Fig. 10B. It is also to be appreciated that the head of the screw may include an outer surface having a substantially untapered portion along with a tapered portion proximate its end for expanding the ring 118.

As described herein, a “ring” is taken to mean any member capable of fitting between the inner surface 113 borehole and the bone screw 120 to connect the bone screw to the bone plate 110. The ring is preferably substantially circular to surround head 125, but the ring may instead have a non-circular shape. The ring may be made of a number of biocompatible materials including metals, plastics, and composites.

It is believed that using a threading engagement between the head 125 and ring 118 increases the hoop stress exerted on head 125, resulting in a stronger connection

between the bone screw 120 and the plate 110. Moreover, if bone threading 136 becomes loose within a bone, screw backout from plate 110 will tend to be resisted by the threaded connection between the screw head 125 and the ring 118. Thus, even if the shank 135 loosens within the bone, the head will tend to remain within the borehole of the plate so as not to protrude from the plate into surrounding body tissue.

As shown in Fig. 9, the head threading 121 on the head 125 and the ring threading 119 on the inner surface of ring 118 is preferably substantially fine relative to the threading 136 on bone screw 120. That is, the pitch of the head threading 121 and ring threading 119 is preferably smaller than that on bone screw 120. The ring threading 119 preferably has multiple starts to facilitate connection of the bone screw and the ring. In one embodiment, the ring threading 119 has a double start such that the head can be started into the ring threading at either one of two orientations offset by 180 degrees. In another embodiment, the ring threading has a triple start such that the head can be started into the ring threading at any one of three orientations offset by 120 degrees.

The ring threading 119 and head threading 121 are preferably pitched to a substantially similar degree to the threading 136 on the bone screw 120. Preferably, the ring threading 119 and head threading 121 are pitched such that the head 125 causes expansion of the ring 118 while the bone screw 120 is being inserted into the bone.

During the surgical procedure for attaching the plate 110 to a bone, holes may be drilled and tapped into the bones to which plate 110 is to be attached. Plate 110 may then be positioned adjacent to the bones. A ring 118 may be positioned within the borehole. A bone screw 120 may be positioned through ring 118 such that the head threading 121 of head 125 engages the ring threading 119 of ring 118. The bone screw 120 may then be rotated to insert the bone screw into the bone. As the screw is rotated the head threads and ring threads preferably interact such that the head is moved into the ring. Movement of the head 125 into the ring 118 preferably causes the ring to expand such that the orientation of the bone screw 120 relative to the plate 110 is fixed. Preferably, the ring

threading and head threading is pitched such the orientation of the bone screw 120 is fixed after plate 110 engages the bone.

The bone screws may be used in pairs to prevent screw backout. The bone screws are preferably positioned into the bone in substantially converging or substantially diverging directions relative to one another.

In an embodiment, a stronger connection between the bone screw 120 and the plate 110 may be formed by texturing either outer surface 131 of head 125 of bone screw 120 or inner surface 133 of ring 118, as depicted in Fig. 13. Preferably, both surfaces are textured to inhibit movement of the bone screw with respect to the plate. During typical manufacturing procedures, outer surface 131 of head 125 and inner surface 133 of ring 118 may be formed as relatively smooth surfaces. While the friction between these smooth surfaces tends to be sufficient to maintain bone screw 120 in a fixed position with respect to plate 110, under stressful conditions the bone screw may be forced out of ring 118. By providing at least one textured surface, the coefficient of friction of the surface may be increased so that a large amount of force is needed to overcome the frictional connection between head 125 of bone screw 120 and ring 118. This increase in friction between bone screw 120 and ring 118 may further inhibit screw backout from plate 110.

A number of textured surfaces may be used to increase the coefficient of friction between ring 118 and head 125 of bone screw 120. In general, any process which transforms a relatively smooth surface into a roughened surface having an increased coefficient of friction may be used. Methods for forming a roughened surface include, but are not limited to: sanding, forming grooves within a surface, ball peening processes, electric discharge processes, and embedding of hard particles within a surface.

In one embodiment a plurality of grooves may be formed in outer surface 131 of head 125 of bone screw 120 or inner surface 133 of ring 118. Preferably, a plurality of grooves is formed in both outer surface 131 and inner surface 133. While it is preferred

that both outer surface 131 and the inner surface 133 be textured, texturing of only one of the surfaces may be sufficient to attain additional resistance to movement.

In another embodiment, the frictional surface may be created by an electrical discharge process. An electrical discharge process is based on the principle of removal of portions of a metal surface by spark discharges. Typically a spark is generated between the surface to be treated and an electrode by creating potential differential between the tool and the electrode. The spark produced tends to remove a portion of the surface disposed between the electrode and the surface. Typically, the electrode is relatively small such that only small portions of the surface are removed. By moving the electrode about the surface numerous cavities may be formed within the surface. Typically these cavities are somewhat pyramidal in shape. Various patterns may be formed within the surface depending on how the electrode is positioned during the discharge. Electric discharge machines are well known in the art. A method for forming a frictional surface within a metal surface using an electric discharge process is described in U.S. Patent No. 4,964,641 to Miesch et al. which is incorporated by reference as if set forth herein.

A variety of patterns may be formed using an electric discharge machine. Preferably a diamond pattern or a waffle pattern is formed on either inner surface 133 of ring 118 or outer surface 131 of head 125 of bone screw 120.

In another embodiment, inner surface 131 of ring 118 and/or outer surface 133 of head 125 of bone screw 120 may be textured by the use of a shot peening process. A shot peening process for forming a textured surface is described in U.S. Patent No. 5,526,664 to Vetter which is incorporated by reference as if set forth herein. In general, a shot peening process involves propelling a stream of hardened balls, typically made of steel, at a relatively high velocity at a surface. To create a pattern upon an area of the surface the stream is typically moved about the surface. The speed by which the stream is moved about the surface tends to determine the type of textured surface formed.

Preferably, the stream is moved such that a pattern resulting in a textured surface having ridges and valleys is formed on inner surface 133 of ring 118 and outer surface 131 of head 125 of bone screw 120. When the textured inner surface 131 of ring 118 and the textured head 125 of bone screw 120 are coupled together the ridges and valleys may interact with each other to provide additional resistance to movement in either a longitudinal direction or a direction perpendicular to the longitudinal axis.

In another embodiment, the textured surface may be produced by embedding sharp hardened particles in the surface. A method for embedding sharp hardened particles in a metal surface is described in U.S. Patent No. 4,768,787 to Shira which is incorporated by reference as if set forth herein. The method of Shira involves using a laser or other high energy source to heat the surface such that the surface melts in selected areas. Just before the molten area re-solidifies, a stream of abrasive particles is directed to the area. In this manner some of the particles tend to become embedded within the molten surface. The particles typically have a number of sharp edges that protrude from the surface after the particles have been embedded within the surface.

Any of the above methods of texturing may be used in combination with another method. For example, outer surface 131 of head 125 of bone screw 120 may be textured using a pattern of grooves. Inner surface of ring 118, however, may be textured using an electrical discharge method. When coupled together the textured surfaces of bone screw 120 and ring 118 may interact with each other to provide additional resistance to movement in either a longitudinal direction or a direction perpendicular to the longitudinal axis.

Textured surfaces may also be formed on any of the other surfaces of the plate system. The formation of textured surfaces preferably increases the frictional resistance between the various components of the plate system.

Further modifications and alternative embodiments of various aspects of the invention will be apparent to those skilled in the art in view of this description.

Accordingly, this description is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the general manner of carrying out the invention. It is

- 5 to be understood that the forms of the invention shown and described herein are to be taken as the presently preferred embodiments. Elements and materials may be substituted for those illustrated and described herein, parts and processes may be reversed, and certain features of the invention may be utilized independently, all as would be apparent to one skilled in the art after having the benefit of this description of the invention.
- 10 Changes may be made in the elements described herein without departing from the spirit and scope of the invention as described in the following claims.

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